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Noise Attenuation Performance of the Lightning II Generation II Helmet when worn in combination with the Joint Service Aircrew Mask (JSAM)- Joint Strike Fighter (JSF)

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14. ABSTRACT
Noise attenuation measurements were conducted by the AFRL on the Lightning II Generation II (Gen II) Helmet Mounted Display (HMD) when worn in combination with the Joint Service Aircrew Mask (JSAM)-Joint Strike Fighter (JSF) at WPAFB in October 2012. ANSI S12.6 and S12.42 were used to measure the passive attenuation and active insertion loss performance respectively. The objective of this study was to determine if the JSAM-JSF hood would meet the noise attenuation performance requirement. When comparing the total noise attenuation of the Gen II HMD with and without the JSAM-JSF, a degradation of 3 dB or more was found in multiple frequencies with the addition of the hood. This degradation was due to the large reduction of active insertion loss. The addition of communication earplugs worn in combination with both the helmet and the hood provided more passive attenuation. Still degradation was found at the lower frequencies (125 and 250 Hz).

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SAM, JSF, Gen II HMD, noise attenuation, REAT, MIRE, active insertion loss, CEP

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TABLE OF CONTENTS

1.0 INTRODUCTION 1
2.0 METHODS 3
2.1 REAT 5
2.2 MIRE 6
2.3 Total Attenuation Calculation 8
3.0 RESULTS 8
3.1 REAT – Passive Attenuation 8
3.2 MIRE – Passive and Active Insertion Loss 9
3.3 Total Attenuation.. 10
4.0 DISCUSSION 12
5.0 CONCLUSION 14
6.0 REFERENCES 14

LIST OF FIGURES

Figure 1. a. F-35 Gen II HMD b. JSAM-JSF hood 2
Figure 2. a. CEP passive, foam tip earplugs b. Subject wearing CEP 3
Figure 3. Male subject wearing the JSAM-JSF in combination with the Gen II HMD 4
Figure 4. Subject in REAT chamber collecting open ear thresholds 6
Figure 5. Subject sitting in MIRE facility (occluded ear condition) 7
Figure 6. a. Acoustic Test Fixture (ATF) b. ATF in MIRE facility (occluded ear condition) 7
Figure 7. Mean minus 2 standard deviation passive attenuation results comparing the Gen II HMD with and without the JSAM-JSF configurations 9
Figure 8. Mean active insertion loss results comparing the Gen II HMD with and without JSAM-JSF configurations 10
Figure 9. Total attenuation results comparing the Gen II HMD with and without JSAM-JSF configurations 12
Figure 10. Total attenuation results comparing the JSAM-JSF requirement to both JSAM-JSF configurations 12
Figure 11. Total attenuation results comparing the Gen II HMD requirement, JSAM-JSF requirement, and the Gen II HMD, JSAM-JSF, and CEP worn in combination 13

LIST OF TABLES

Table 1. . F-35 Gen II HMD (JSF02623 earcups) total noise attenuation performance and the JSAM-JSF Requirement (Gen II HMD minus 3 dB) per octave band 3
Table 2. Anthropometric head and neck measurements for participating subjects* 4
Table 3. Gen II HMD and JSAM-JSF sizes for participating subjects 5
Table 4. Mean and standard deviation passive attenuation results from REAT measurements 9
Table 5. Mean passive insertion loss results from MIRE measurements 9
Table 6. Mean active insertion loss results from MIRE measurements 10
Table 7. Total attenuation results calculated from MIRE measurements 11
Table 8. Total attenuation results calculated from REAT and MIRE measurements 11

EXECUTIVE SUMMARY

Noise attenuation performance measurements were collected on the Joint Service Aircrew Mask (JSAM)-Joint Strike Fighter (JSF) hood worn in combination with the F-35 Lightning II Generation II (Gen II) Helmet Mounted Display (HMD) at the Air Force Research Laboratory's (AFRL) acoustics facilities at Wright-Patterson Air Force Base in October 2012. The noise attenuation performance was measured for an additional configuration that included the JSAM-JSF hood, Gen II HMD, and Communication Earplugs (CEP). American National Standards Institute (ANSI) methods were used to measure the passive attenuation and the active insertion loss of the systems in order to calculate the total noise attenuation performance. Passive attenuation was measured using the ANSI S12.6-1997(R2002)[1] Methods for Measuring the Real-Ear Attenuation (REAT) of Hearing Protectors, Method A, while passive and active insertion loss was measured using ANSI S12.42-2010[2] Methods for the Measurement of Insertion Loss of Hearing Protection Devices in Continuous or Impulsive Noise Using Microphone-in-Real-Ear (MIRE) or Acoustic Test Fixture Procedures. Total noise attenuation performance was calculated two different ways for two different reasons. The first calculation included passive and active insertion loss measurements collected using the MIRE method only. The JSAM-JSF requirement stated that MIRE measurements would be used to determine if the current design would meet the requirement. The second calculation included the passive attenuation measurement using REAT methods and the active insertion loss using MIRE methods. This calculation must be used to determine noise exposures for the aircrew. Total noise attenuation performance of both configurations was calculated and compared to the total noise attenuation of the Gen II HMD alone to understand the effect the JSAM-JSF hood may have on the helmet's noise attenuation performance. The JSAM-FW Performance Specification [71] requirement[3] defined that when integrated with the flight helmet, no more than a 3dB degradation of the measured one-third octave band hearing attenuation shall result when compared to the original (helmet only) configuration. The results showed that the JSAM-JSF worn under the Gen II HMD degraded the noise attenuation performance by more than 3 dB at multiple frequencies (both low and high) when compared to the noise attenuation of the helmet alone. When CEP was added to the configuration, the total noise attenuation results (using REAT and MIRE or MIRE only methods) showed that attenuation at 125 and 250 Hz had degradation greater than 3dB when compared to the helmet alone. The addition of passive earplugs improved the attenuation performance at high frequencies. However, when the seal of the active noise reduction (ANR) earcup was broken by the JSAM-JSF hood, the degradation in the low frequencies could not be improved with the addition of a passive protector.

1.0 INTRODUCTION

JSF aircrews don the F-35 Lightning II Gen II HMD, a Vision Systems International (VSI) product, to combat noise in the cockpit and provide satisfactory voice communication capabilities. Noise attenuation performance measurements were previously collected in August 2012 on the Gen II HMD (Figure 1a) alone at AFRL, 711th Human Performance Wing, Human

Effectiveness Directorate, Warfighter Interface Division, Battlespace Acoustics Branch (711 HPW/RHCB). Table 1 displays the Gen II HMD total noise attenuation per octave band. The helmet system included a Helmet Assembly Unit, fit adjustment and retention system, bi-ocular display unit (including display and external tinted visors in down position) mounted to the helmet, generic liner pads, Helmet Integrated System Ltd (HISL) ANR earcups (part number JS02623) and a MBU-23/P oxygen mask with customized bayonets.

a. **b.**

Figure 1. a. F-35 Gen II HMD b. JSAM-JSF hood

The JSAM-JSF is worn in combination with the Gen II HMD to provide the chemical/biological (CB) protection to the respiratory system in an actual or perceived CB warfare environment. The JSAM-JSF hood provides "above the neck" head-eye-respiratory and percutaneous protection against CB warfare agents, radiological particles, and continuous protection against CB agent permeation for both ground and in-flight operations (Figure 1b). The JSAM-JSF provides the capability for aircrew to fly throughout their full operating envelope and perform their mission in a CB warfare environment.

The objective of this study was to measure the total noise attenuation performance of the JSAM-JSF when worn in combination with the Gen II HMD and to determine if the JSAM-JSF noise attenuation requirement was met (Table 1). The JSAM-JSF requirement[3] is shown below.

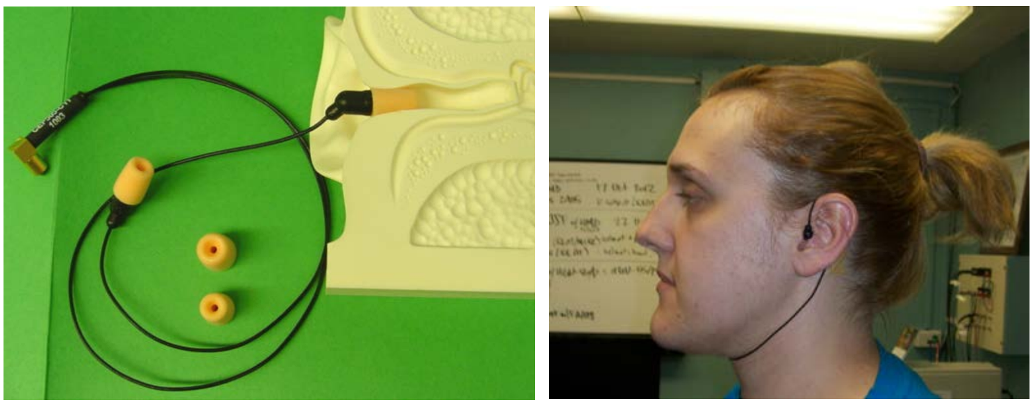
> JSAM Specification Paragraph 3.4.9.3, item 71 (Reference 3)[3]:
>
> *The JSAM when integrated with existing head-mounted personal/life support equipment in Appendix E shall result in no more than a 3 dB degradation of the measured one-third octave band hearing attenuation compared to the original (non-JSAM) configuration.*

Additional noise attenuation measurements were collected on a second configuration that included the helmet, hood, and passive CEP. The CEP (Figure 2) are generic, foam tip, earplugs

that provide both protection and communications. CEP plugs were selected to provide added passive noise attenuation and to improve communication capabilities when the hood was donned.

Table 1. . F-35 Gen II HMD (JSF02623 earcups) total noise attenuation performance and the JSAM-JSF Requirement (Gen II HMD minus 3 dB) per octave band

	Frequency (Hz)						
	125	**250**	**500**	**1000**	**2000**	**4000**	**8000**
Gen II HMD (JSF02623 earcups)	26.4	22.7	18.7	22.4	26.5	49.2	51.8
JSAM-JSF Requirement	23.4	19.7	15.7	19.4	23.5	46.2	48.8



a. **b.**

Figure 2. a. CEP passive, foam tip earplugs b. Subject wearing CEP

2.0 METHODS

All passive and active noise attenuation measurements were collected on the JSAM-JSF worn in combination with the Gen II HMD with and without CEP (Figure 3). Ten paid volunteer subjects (5 male, 5 female) participated in the first configuration – Gen II HMD. Twenty subjects (the initial 10 subjects with an additional 10 subjects (4 male, 6 female)), participated in the second configuration - Gen II HMD with CEP. All subjects had hearing threshold levels less than or equal to 25 dB HL from 125 to 8000 Hz. Anthropometric head and neck measurements were collected for each subject, as shown in Table 2. Table 3 lists the size of the Gen II HMD and JSAM-JSF for the participating subjects. The subjects who participated in both configurations have an * next to their subject ID number. All subjects were expertly fit by representatives from Gentex, VSI, and the JSF Program Office to ensure proper Gen II HMD and JSAM-JSF fit procedures[4].

Figure 3. Male subject wearing the JSAM-JSF in combination with the Gen II HMD

Table 2. Anthropometric head and neck measurements for participating subjects

Subject ID	Anthropometric Head and Neck Measurements (cm)				
	Head Circumference	Head Length	Head Width	Nasal Root to Supramentale	Neck Circumference
1438*	57.7	19.4	15.5	88.9	36.1
1524*	57.0	19.3	15.5	82.5	40.5
1526*	57.0	19.4	16.0	82.0	42.5
1572*	62.5	21.0	16.7	91.0	43.0
1208*	57.5	19.3	15.2	95.2	39.5
1496*	57.0	18.8	15.0	82.0	36.0
1550*	57.5	19.5	15.2	87.0	39.0
1436*	60.0	20.0	16.3	92.7	43.0
1534*	56.5	19.0	15.7	92.0	39.0
1382*	57.0	19.1	14.8	83.0	32.0
1487	57.1	19.3	15.0	88.9	34.2
1569	53.5	18.3	14.1	82.5	32.0
1574	59.5	20.2	16.2	92.0	40.0
1553	58.5	19.3	16.2	88.0	40.5
1576	62.0	21.2	16.0	94.0	44.0
1567	57.5	19.8	15.2	87.0	31.5

-Did not collect anthropometric measurements on subjects 1561, 1573, 1578, and 1546

Table 3. Gen II HMD and JSAM-JSF sizes for participating subjects

Subject ID	Size	
	Gen II HMD	JSAM-JSF
1438*	M	M/MN
1524*	M	M/MN
1526*	M	M/MW
1572*	L	L/LW
1208*	L	M/MN
1496*	M	M/MW
1550*	M	M/MW
1436*	L	L/LW
1534*	M	M/MW
1382*	M	M/MN
1487	M	M/MN
1561	M	M/MW
1569	M	M/MN
1573	M	M/MN
1574	L	L/MN
1553	L	L/LW
1576	L	L/LW
1578	L	L/LW
1567	M	M/MW
1546	L	L/LW

2.1 REAT

The AFRL REAT facility was used to measure the passive attenuation performance of hearing protectors. The facility was built for the measurement, analysis, and documentation of the sound attenuation properties of passive hearing protection devices. The chamber, its instrumentation, and measurement procedures were in accordance with ANSI S12.6-1997(R2002).[1] The 2008 version of ANSI S12.6 was not used in order to directly compare the JSAM-JSF and Gen II HMD configurations with and without CEP to the data collected on the Gen II HMD alone. The procedures described in ANSI S12.6 consist of measuring the open ear (without the hearing protector) and occluded ear (with the hearing protector) hearing thresholds of human subjects using a von Békésy tracking task. These psychoacoustic thresholds were measured two times for the open condition and two times for the unoccluded condition. The real-ear attenuation at threshold for each subject was computed at each frequency, 125 to 8000 Hz, by averaging the difference between the open and occluded threshold measurements. The mean and standard deviation were then calculated for all the subjects. Figure 4 is a side view of a female subject inside the REAT chamber during an open ear condition.

Figure 4. Subject in REAT chamber collecting open ear thresholds

2.2 MIRE

The AFRL MIRE facility was used to measure the passive and active insertion loss of the hearing protector. Insertion loss is defined as the algebraic difference in dB between the sound pressure levels (SPL) measured at a reference point with and without the hearing protector in place. The facility and measurements were operated in accordance with ANSI S12.42-2010.[2] The same 10 subjects (5 male, 5 female) described above participated wearing the first configuration (helmet and hood). However, for the second configuration (helmet, hood, and earplugs) an acoustic test fixture (ATF) was required in order to objectively measure the SPL under the earplug.

To measure the passive and active insertion loss using human subjects, miniature microphones (Knowles model BT-1759) were used to simultaneously measure the SPL at the entrance of both ear canals. 115 dB overall SPL was generated and three objective measurements were collected to complete one trial: open, occluded ANR off, and occluded ANR on. The ANR was powered by a portable 20 volt power supply (Figure 5). Three trials were collected per subject. For each subject, the mean of the three measurements was computed (open and occluded). Mean passive and active insertion loss for the 10 subjects were then calculated.

Figure 5. Subject sitting in MIRE facility (occluded ear condition)

The ATF used for these measurements was an ISL-1 type head (Figure 6) equipped with ¼" microphones to simultaneously measure the SPL with and without the hearing protector. The same noise and methodology explained above was followed for these measurements.

a. b.

Figure 6. a. Acoustic Test Fixture (ATF) b. ATF in MIRE facility (occluded ear condition)

2.3 Total Attenuation Calculation

Total noise attenuation performance of both configurations was calculated and compared to the total noise attenuation of the Gen II HMD alone to understand the effect the JSAM-JSF hood may have on the helmet's noise attenuation performance. The total noise attenuation was calculated two different ways for two different reasons. The JSAM-JSF requirement stated that MIRE measurements would be used to determine if the current design would meet the requirement. This calculation added the mean passive and active insertion loss measurements collected using the MIRE method only. The second calculation added the mean active insertion loss data (using the MIRE method) to the mean minus two standard deviation passive attenuation data (using the REAT method). This total noise attenuation calculation is required to estimate noise exposures for the F-35 aircrew. All total attenuation calculations were compared to the JSAM-JSF noise attenuation requirement listed in Table 1.

3.0 RESULTS

The passive attenuation performance and passive and active insertion loss measurements of the JSAM-JSF worn in combination with the F-35 Gen II HMD with and without CEP was measured at AFRL. REAT (passive attenuation), MIRE (passive and active insertion loss), and total attenuation (passive plus active calculation) results were analyzed to determine what effect, if any, the hood may have on the hearing protection system.

3.1 REAT – Passive Attenuation

Passive attenuation performance was measured with the F-35 Gen II HMD and the JSAM-JSF worn in combination with and without CEP in AFRL's REAT facility. Mean and standard deviation results from 125 to 8000 Hz for all subjects are shown numerically in Table 4 and graphically in Figure 6 for the helmet, helmet and hood, and helmet, hood and earplug configurations. The addition of the hood under the helmet degrades the passive noise attenuation when compared to the helmet alone configuration across all frequencies. When the CEP is added to the configuration, passive noise attenuation was found to be the same or greater than the attenuation in the helmet alone condition.

Table 4. Mean and standard deviation passive attenuation results from REAT measurements

		Frequency (Hz)						
		125	**250**	**500**	**1000**	**2000**	**4000**	**8000**
Gen II HMD (JSF02623 earcups)	Mean	18	13	12	33	39	53	59
	SD	4	4	3	4	3	2	4
Gen II HMD with JSAM-JSF	Mean	15	13	13	30	37	53	54
	SD	6	5	5	4	5	7	8
Gen II HMD with JSAM-JSF and CEP	Mean	20	20	25	42	44	61	66
	SD	5	5	6	5	3	5	5

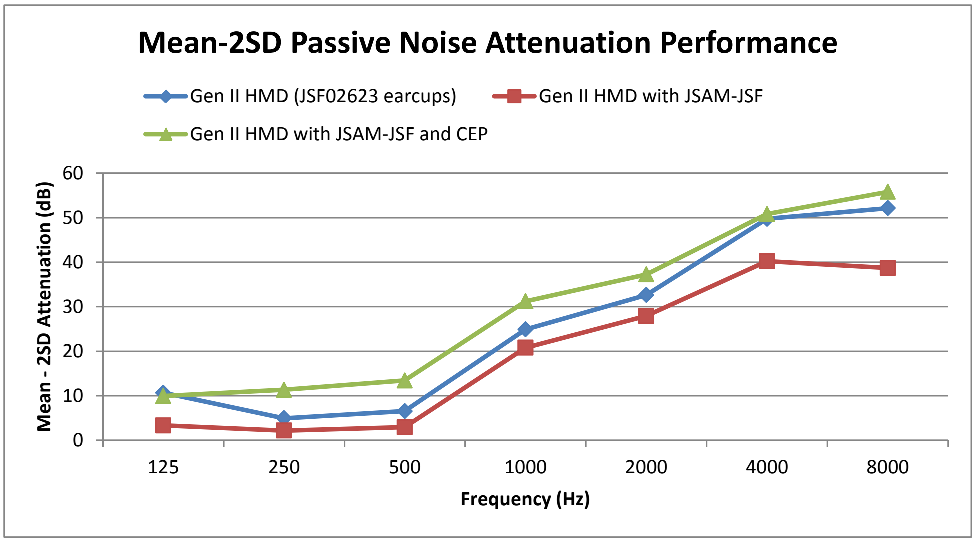


Figure 7. Mean minus 2 standard deviation passive attenuation results comparing the Gen II HMD with and without the JSAM-JSF configurations

3.2 MIRE – Passive and Active Insertion Loss

Passive and active insertion loss measurements were collected using both human subjects and an ATF in AFRL's MIRE facility on the JSAM-JSF worn in combination with the Gen II HMD with and without CEP. Mean passive insertion loss data from 125 to 8000 Hz is listed in Table 5. Mean active insertion loss data from 125 to 8000 Hz is shown numerically in Table 6 and graphically in Figure 8. The addition of the hood under the helmet significantly degrades the active noise reduction capability of the helmet's ANR earcups with and without CEP.

Table 5. Mean passive insertion loss results from MIRE measurements

	Frequency (Hz)						
	125	**250**	**500**	**1000**	**2000**	**4000**	**8000**
Gen II HMD with JSAM-JSF	3.27	6.26	10.28	23.55	30.31	44.41	44.00
Gen II HMD with JSAM-JSF and CEP	4.03	13.03	30.00	46.95	59.05	67.07	59.13

Table 6. Mean active insertion loss results from MIRE measurements

	Frequency (Hz)						
	125	250	500	1000	2000	4000	8000
Gen II HMD (JSF02623 earcups)	15.71	17.80	12.15	-2.47	-6.07	-0.55	-0.30
Gen II HMD with JSAM-JSF	1.76	2.91	7.07	-0.05	0.10	0.37	0.33
Gen II HMD with JSAM-JSF and CEP	-0.22	1.35	6.57	-0.37	-0.30	-0.02	0.00

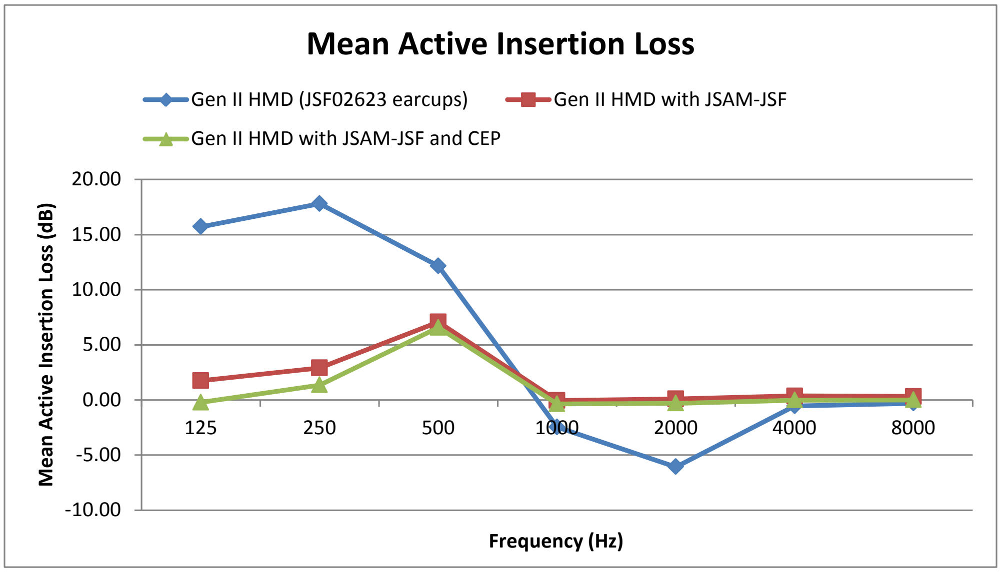


Figure 8. Mean active insertion loss results comparing the Gen II HMD with and without JSAM-JSF configurations

3.3 Total Attenuation

Total attenuation performance for the JSAM-JSF worn in combination with the Gen II HMD with and without the CEP was calculated. Two different calculations methods were used. The first calculation added the passive and active insertion loss data (using MIRE methods only) for both configurations to determine if the JSAM-JSF requirement was met (Table 7). The JSAM-JSF, when worn in combination with the Gen II HMD, degraded the attenuation performance by more than 3 dB at 125, 250, and 8000 Hz. The addition of the CEP improved the attenuation at 8000 Hz, but degradation of more than 3 dB was still found at 125 and 250 Hz.

Table 7. Total attenuation results calculated from MIRE measurements

	Frequency (Hz)						
	125	**250**	**500**	**1000**	**2000**	**4000**	**8000**
Gen II HMD with JSAM-JSF	5.02	9.18	17.35	23.51	30.41	44.78	44.32
Gen II HMD with JSAM-JSF and CEP	3.82	14.38	36.57	46.58	58.75	67.05	59.13
JSAM-JSF Requirement	23.36	19.74	15.68	19.44	23.54	46.17	48.82

The second total noise attenuation calculation was completed by adding the mean minus 2 standard deviation passive attenuation data (using the REAT method) to the mean active insertion loss data (using the MIRE method) across all seven frequencies. Total attenuation data are shown numerically in Table 8 and graphically in Figure 9 for all configurations. The JSAM-JSF requirement (Gen II HMD total noise attenuation minus 3 dB per octave band) is also included in Table 8. Figure 10 graphically compares the total noise attenuation of the JSAM-JSF configurations with the JSAM-JSF requirement. The total attenuation results show that the JSAM-JSF degrades the total noise attenuation performance of the Gen II HMD at 125, 250, 500, 4000, and 8000 Hz by more than 3 dB. The total attenuation results, comparing the helmet alone to the helmet, hood, and earplugs, show that degradation greater than 3 dB occurs at 125 and 250 Hz.

Table 8. Total attenuation results calculated from REAT and MIRE measurements

	Frequency (Hz)						
	125	**250**	**500**	**1000**	**2000**	**4000**	**8000**
Gen II HMD (JSF02623 earcups)	26.36	22.74	18.68	22.44	26.54	49.17	51.82
Gen II HMD with JSAM-JSF	5.08	5.09	10.02	20.73	28.00	40.57	39.00
Gen II HMD with JSAM-JSF and CEP	9.70	12.69	19.99	30.84	36.95	50.80	55.78
JSAM-JSF Requirement	23.36	19.74	15.68	19.44	23.54	46.17	48.82

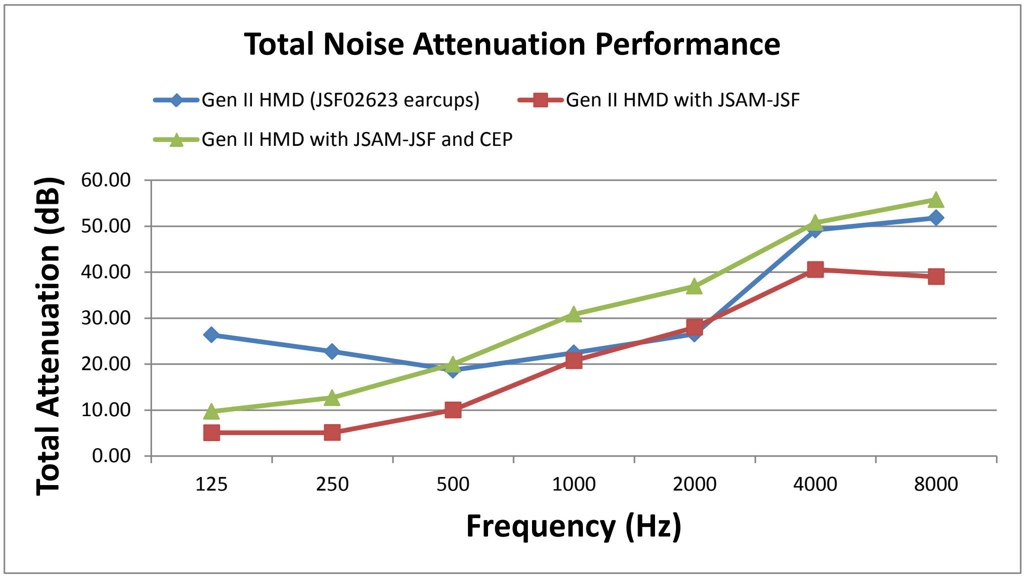


Figure 9. Total attenuation results comparing the Gen II HMD with and without JSAM-JSF configurations

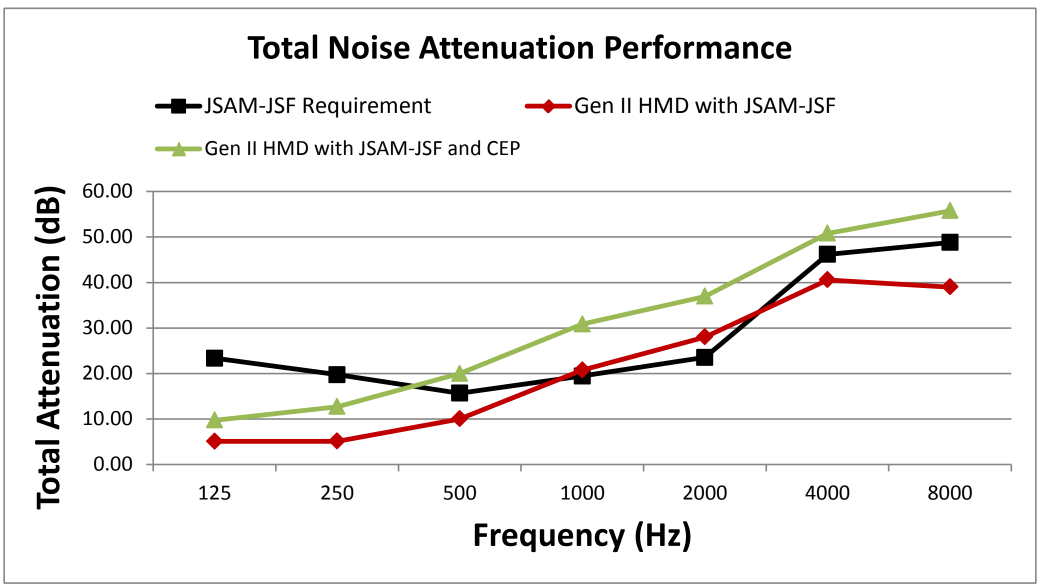


Figure 10. Total attenuation results comparing the JSAM-JSF requirement to both JSAM-JSF configurations

4.0 DISCUSSION

It is well known that the addition of a CB hood worn in combination with a flight helmet will negatively affect the noise attenuation performance of the system. The JSAM-JSF requirement was written with this in mind and stated that the hood shall not degrade the noise attenuation performance of the helmet by more than 3 dB per frequency to reduce the risk of noise-induced hearing loss and to maintain communication capabilities. When comparing the Gen II HMD

with and without the JSAM-JSF, total noise attenuation degradation greater than 3 dB was found at multiple high and low frequencies.

Passive communication earplugs were added to the configuration not only to improve noise attenuation, but also to potentially improve communications. When comparing the Gen II HMD with and without the JSAM-JSF and CEP, total noise attenuation degradation greater than 3 dB was found only at the low frequencies (125 and 250 Hz). To compare the total noise attenuation of the helmet, hood, and earplugs to the Gen II HMD attenuation requirement (Figure 11) the only degradation greater than 3 dB was found at 125 Hz. It was not a surprise to see the improvements at the high frequencies, where passive protection is the most effective. However, the degradation of the ANR performance, caused by the break in the seal of the earcup around the user's ears, was significant for both configurations (with and without CEP). The reduction in active insertion loss with the addition of the JSAM-JSF could potentially be improved by fully integrating the ANR earcups of the Gen II HMD into the JSAM-JSF design. This would eliminate the material under the earcup that adversely affects the ANR capability. This integration would be a complete redesign of the hood and donning/doffing the hood and helmet could be troublesome for the aircrew. The addition of earplugs clearly improved high frequency attenuation, but aircrew acceptability and the aircrew's physical ability to wear earplugs could be an issue.

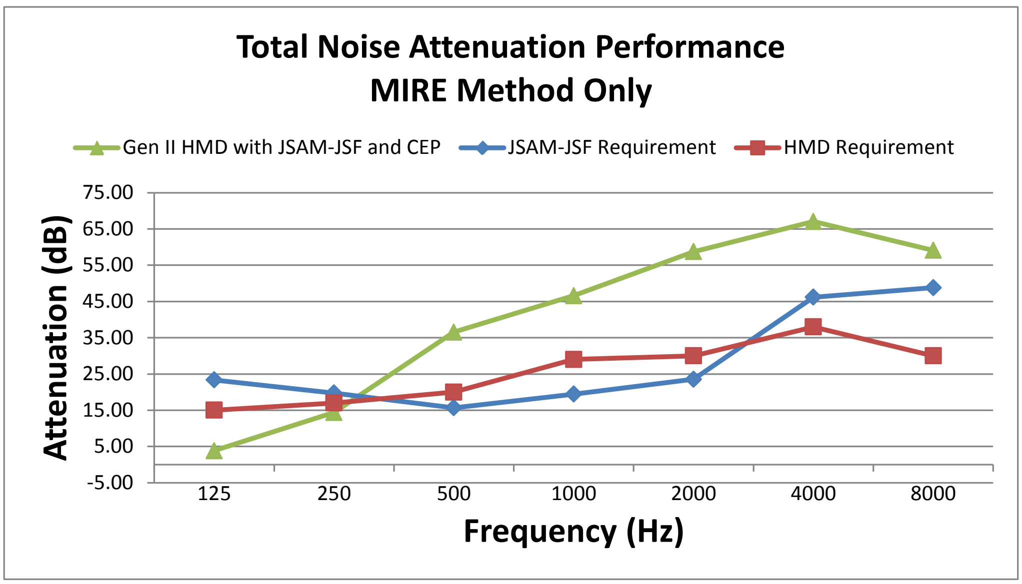


Figure 11. Total attenuation results comparing the Gen II HMD requirement, JSAM-JSF requirement, and the Gen II HMD, JSAM-JSF, and CEP worn in combination

The total noise attenuation results (using REAT and MIRE methods), although failing to meet the JSAM-JSF requirement at all frequencies, could be applied to the noise generated during a normal flight profile to calculate the pilots' total daily exposure (TDE). The TDE must be equal to or less than 1.0 in order to reduce the risk of noise induced hearing loss.

5.0 CONCLUSION

The JSAM-JSF is crucial in protecting the aircrew from respiratory hazards when flying in a CB warfare environment. In order to also protect the aircrew from noise induced hearing loss and to preserve proper communications when the JSAM-JSF is worn in combination with the helmet, no more than 3 dB of noise attenuation degradation is acceptable across all frequencies when compared to the helmet alone. When comparing the total attenuation of the Gen II HMD with and without the JSAM-JSF, a degradation of 3 dB or more was found at multiple frequencies (both low and high) with the addition of the JSAM-JSF. This degradation was due to the reduction of active insertion loss provided by the ANR earcups. The addition of passive CEP to the system (helmet and hood) improved the attenuation performance in the high frequencies, but still degraded the performance at 125 and 250 Hz by more than 3 dB.

6.0 REFERENCES

1. ANSI S12.6-1997(R2002) American National Standard Methods for Measuring the Real-Ear Attenuation of Hearing Protectors.
2. ANSI S12.42-2010 American National Standard Methods for the Measurement of Insertion Loss of Hearing Protection Devices in Continuous or Impulsive Noise Using Microphone-in-Real-Ear (MIRE) or Acoustic Test Fixture Procedures.
3. F-35 Lightning II Gen II HMD and JSAM Noise Attenuation Test Plan, March 1, 2012, Document No: 2ZCA12339, Lockheed Martin CAGE Code: 81755.
4. Whitaker, K. (2008) Joint Strike Fighter (JSF) Aerospace Equipment Instruction (AEI) Helmet Mounted Display (HMD) Donning/Doffing Procedure (Reference: 2ZUA05009, Rev. A). April 7, 2008.